LIGHT-BEAM MICROPHONE AND METHOD

Original Filed April 18, 1960 2 Sheets-Sheet 1

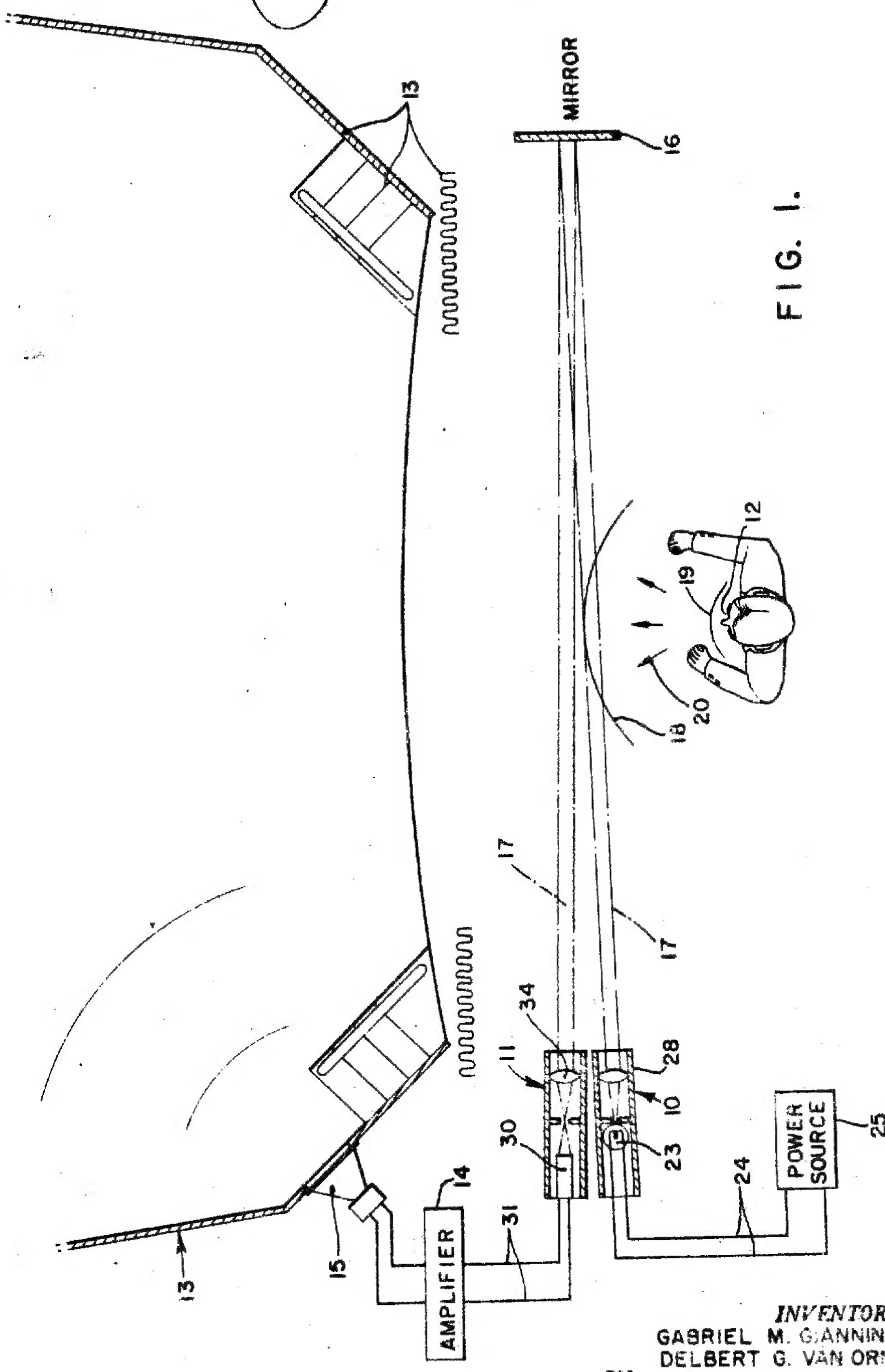

FIG. 1.

INVENTORS.
GABRIEL M. GIANNINI
DELBERT G. VAN ORNUM
BY
ATTORNEY.

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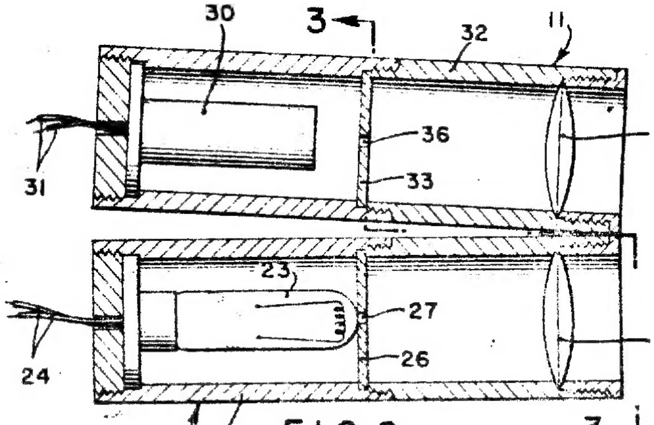

FIG. 2.

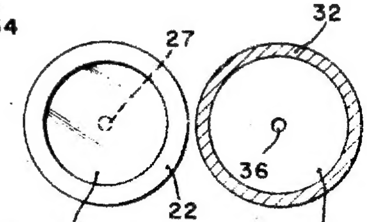

FIG. 3.

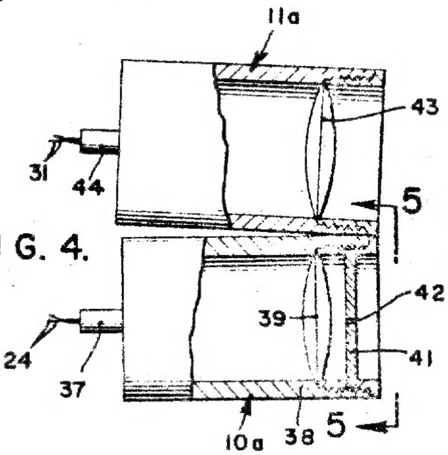

FIG. 4.

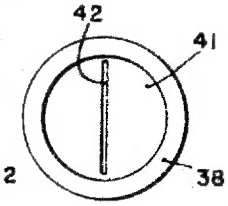

FIG. 5.

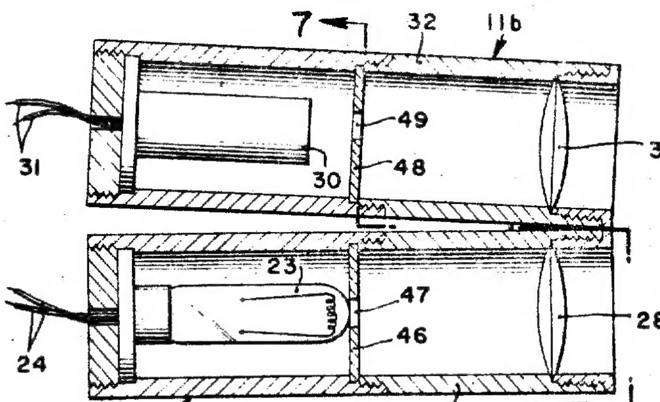

FIG. 6.

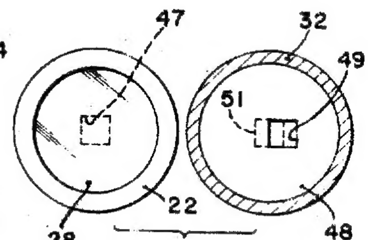

FIG. 7.

INVENTORS.
GABRIEL M. GIANNINI
DELBERT G. VAN ORNUM

BY

ATTORNEY.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,229,098 January 11, 1966

Gabriel M. Giannini et al

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 10, for "dispensing" read -- disposing --.

Signed and sealed this 21st day of March 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents

3,229,098

LIGHT-BEAM MICROPHONE AND METHOD

Gabriel M. Giannini, Indio, and Delbert G. Van Ornum, Newport Beach, Calif., assignors, by mesne assignments, to Giannini Scientific Corporation, Long Island, N.Y., a corporation of Delaware

Continuation of application Ser. No. 22,873, Apr. 18 1960. This application Jan. 15, 1963, Ser. No. 252,544
7 Claims. (Cl. 250—199)

This invention relates to a method and apparatus for transducing air-borne sound vibrations into electrical signals through use of a beam of light. The present application is a continuation of our co-pending patent application Serial No. 22,873, filed April 18, 1960 for a Light-Beam Microphone and Method, now abandoned.

An object of the present invention is to provide a microphone apparatus and method wherein all equipment may be located a considerable distance from the source of sound, so that the problem of excluding a microphone from a television picture is eliminated.

Another object is to provide a light-beam microphone and method characterized by a minimum of interference from sounds other than the one which it is desired to transduce into an electrical signal.

A further object of the invention is to provide a method and apparatus for improving the high-frequency response of a light-beam microphone.

These and other objects and advantages of the invention will be more fully set forth in the following specification and claims, considered in connection with the attached drawings to which they relate.

In the drawings:

FIGURE 1 is a schematic plan view illustrating a speaker on a stage, and showing the relationship between such speaker and a first form of apparatus embodying the present invention;

FIGURE 2 is an enlarged horizontal sectional view of the light-transmitting and light-receiving portions of the apparatus;

FIGURE 3 is a vertical section taken on the broken line 3—3 of FIGURE 2;

FIGURE 4 is a view, partially in horizontal section and partially in plan, illustrating a second form of apparatus incorporating the invention;

FIGURE 5 is a fragmentary end elevation, as viewed from station 5—5 of FIGURE 4;

FIGURE 6 is a horizontal sectional view illustrating a third embodiment of the invention; and

FIGURE 7 is a vertical section taken on the broken line 7—7 of FIGURE 6.

Referring first to the embodiment shown in FIGURES 1–3 of the drawings, the apparatus is illustrated to comprise a light-beam transmitter means 10 and a photodetector means 11 so arranged and constructed that sound waves emanating from a sound source 12 are transduced into corresponding electrical signals. In the present illustration, the sound source comprises the vocal cords and mouth of a performer on a stage in a theater, the latter being schematically indicated at 13. The electrical signals are amplified in suitable amplifier means 14 and then conducted to a loudspeaker 15. It is to be understood that the present apparatus and method are adapted for use in television, motion pictures, etc., as well as for technical purposes such as measuring the sound intensity in the exhaust from a rocket engine.

The transmitter means 10 and photodetector means are disposed closely adjacent each other in the wing at one side of the stage, and a mirror 16 is disposed in a wing at the other side thereof. The means 10 and 11 are so related to each other and to mirror 16 that a light beam 17 projected from transmitter 10 will be reflected

back to photodetector 11 for generation of a photoelectric current therein. At least one of the incident and reflected portions of the light beam 17 is directed through the air in front of sound source 12 and at substantially the same elevation. The beam is accordingly refracted correspondingly to the sound waves because of the different densities of the air at different portions thereof.

It is pointed out that the sound waves emanating from source 12 have the form of sections of spheres, and comprise a plurality of compression fronts (such as 18 and 19) separated by low-pressure regions one of which is indicated at 20. The compression fronts 18 and 19 (and the low-pressure regions) are spaced substantial distances from each other. For example, the compression fronts of a sound wave having a frequency of one thousand cycles per second are approximately one foot apart.

It is within the scope of the invention to employ one or more mirrors on the same side of the stage as the means 10 and 11, in conjunction with a corresponding bank of mirrors adjacent mirror 16. The light beam is thus reflected back and forth across the stage a substantial number of times in order that the deflection at photodetector 11 will be increased. It is emphasized, however, that in embodiments wherein the beam or light is reflected back and forth, different portions of the light beam should not pass through substantially different parts of the sound wave. Thus, it would not be desirable for the incident portion of beam 17 to pass through the compression front 18 and the reflected portion of the beam to pass through the front 19. Thus, the transmitter 10 and the detector means 11 are located closely adjacent each other, so that both the incident and the reflected beam portions pass through substantially the same portion of the wave. It is within the scope of the invention to reflect the beam back and forth between mirrors which are so disposed that the reflected beam portions do not pass through sound waves emanating from source 12.

Referring particularly to FIGURES 2 and 3, the illustrated transmitter means 10 comprises a tubular body 22 having a powerful light source 23 mounted at one end portion thereof, for example an incandescent lamp energized through leads 24 from a source 25 (FIGURE 2) of electric power. A mask 26 is mounted in body 22 closely adjacent source 23, having a small hole or opening 27 therein so that a point source of light is simulated. The illustrated opening 27 is round (FIGURE 3), and should have a small diameter such as a few thousands or hundredths of an inch. Suitable lens means 28 are provided in body 22 on the opposite side of mask 26 from source 23, being adapted to transmit light from opening 27 in parallel rays comprising the light beam 17.

The photodetector means 11 comprises a highly sensitive device 30 for generating a photoelectric current having an amplitude which varies in accordance with the quantity of light transmitted thereto. Stated more definitely, the device 30 is a photomultiplier which may be of conventional construction. Suitable photomultipliers are sold by the Radio Corporation of America under the designations 6199 and 7102. The photoelectric current generated in photomultiplier 30 is transmitted through leads 31 to the amplifier 14, and thence to the loud speaker 15 or other apparatus such as a radio transmitter.

The photomultiplier 30 is mounted in a tubular body 32 having a mask 33 and lens 34 therein. Mask 33 may correspond exactly to mask 26, and have an opening corresponding to opening 27. The lens 34 may correspond exactly to the lens 28 of the transmitter means.

Description of the method with particular reference to the apparatus of FIGURES 1–3

In performing the method with the apparatus illustrated in FIGURES 1–3, the transmitter means 10 and

photodetector means **11** are so aligned with mirror **16** that the reflected portion of light beam **17** will be focused by lens **34** on opening **36** (in complete registry therewith) when there is no sound emanating from source **12**.

When a compression front (such as is numbered **18** in FIGURE 1) of the sound wave from source **12** passes through the light beam **17**, such beam will be refracted slightly due to the different velocities of light in air having different densities. When the refracted beam (which in the illustrated form is also reflected from the mirror **16**) is transmitted to the opening **36** in mask **33**, it will be shifted laterally (horizontally) until it is at least partially out of registry with such opening. The photoelectric current generated by the photomultiplier **30** is reduced accordingly.

It is to be understood that if the note from source **12** has a high frequency, the compression fronts **18** and **19**, etc., will be relatively close together. The light beam **17** will thus be disturbed relatively frequently, so that the resulting photoelectric current will have a higher frequency corresponding to that of the sound wave. If the note from source **12** has a substantial volume, the degree of refraction will be relatively great and the quantity of light transmitted to photomultiplier **30** will be diminished accordingly. The amplitude of the A.C. electrical signal will thus be increased. On the other hand, if the note has a low volume, the degree of refraction of the light beam will be relatively small, and the quantity of light transmitted to the photomultiplier will not be reduced by the same degree as when the note had a strong volume. The A.C. signal will accordingly have a small amplitude. The device is therefore sensitive to both the frequency and volume of the sound wave.

Embodiment of FIGURES 4 and 5

Referring to FIGURES 4 and 5, a transmitter means **10*a*** and photodetector means **11*a*** are illustrated which are adapted to transmit and receive what may be termed a sheet or band of light, as distinguished from a conventional light beam. Transmitter **10*a*** comprises a portion **37** containing a light source and a mask corresponding exactly (as to size, construction and location) to elements **23** and **26** shown in FIGURE 2. The forward portion **38** of transmitter **10*a*** has a diameter many times that of the portion **37**, and contains a large diameter lens **39** and a second mask **41** disposed in advance of such lens.

Mask **41** has a slit **42** therein, such slit being on the order of several inches or several feet in height but having a width of only a few hundredths or tenths of an inch. Thus, instead of the conventional beam transmitted from source **10** of the previous embodiment, the light leaves the transmitter **10*a*** in the form of a sheet or band which is thin but may be several feet in height. Such sheet or band is much more thin than the beam from element **10** of the first embodiment.

Since the width of the slit **42** is very small, and since the distance between each compression and the adjacent rarefaction of even a two thousand cycle note is on the order of inches, it will be apparent that the light beam has a dimension transverse to the direction of beam propagation which is small in comparison to the distance between each compression and rarefaction. Furthermore, as will be set forth below, the beam is in such relationship to the sound waves that the small dimension of the beam is generally in line with the direction of sound propagation.

The photodetector means **11*a*** comprises a lens **43** corresponding exactly to lens **39** and adapted to concentrate the light beam onto an opening in a mask (unshown) disposed in a small-diameter portion **44** of the detector. Portion **44** also contains a photomultiplier corresponding to photomultiplier **30** of the previous embodiment. The opening in the mask (unshown) in portion **44** has such a size and shape that refraction of the light band or beam, as a result of passage of sound waves therethrough from source **12**, varies the signal generated in the photomultiplier. Thus, assuming that the mask location in detector portion **44** is the same as that in transmitter portion **37**, such opening may be a vertical slit having a height corresponding to the diameter of opening **27**, and a width just great enough to receive the entire concentrated beam when no sound is emanating from source **12**. The distance from the transmitter and detector **10** and **11** to mirror **16** may be reduced until only the strongest sound waves cause the concentrated beam to deflect until no part thereof reaches the photomultiplier.

In performing the method with the apparatus of FIGURES 4 and 5, the light-beam transmitter **10*a*** is so oriented that the slit **42** and the sheet or band of light transmitted therefrom are generally perpendicular to the major axis of propagation of the compression fronts, such as **18** and **19**, emanating from source **12**. Thus, when the source **12** is so directed that the primary sound waves are projected forwardly horizontally, transmitter **10*a*** is so oriented that slit **42** and the sheet or band of light are vertical. The light band is then tangential to the spherical compression fronts.

It is within the scope of the invention to make the slit **42** arcuate as distinguished from straight, with the radius of curvature being such that the light band has approximately the same radius of curvature as each compression front **18** or **19**, etc. The band is then so located that it is concentric with the compression (or rarefaction) front passing therethrough. However, the portion of the light band adjacent source **12** is still generally perpendicular to the major axis of wave propagation therefrom.

The light band or sheet transmitted from transmitter means **10*a*** is refracted by the sound waves and is then received by the photodetector means **11*a***. Lens **43** of such means concentrates the light sheet at the opening in the mask adjacent the photomultiplier. The beam (or a portion thereof) then impinges on the photomultiplier to create an A.C. electrical signal corresponding to the sound waves from source **12**.

It is an important feature of the present embodiment that the light beam is very sensitive to the sound waves from source **12**, but insensitive to sound waves which travel in directions generally parallel to the light sheet (for example, vertical) as distinguished from perpendicular thereto. It follows that interference noises are suppressed.

It is another important feature of the embodiment of FIGURE 4 that the high-frequency response of the apparatus is excellent. Because of the thinness of the band or sheet of light, it is sensitive to pressure fronts which are only a short distance apart, as is the case with notes having high frequencies.

It is to be understood that the means **10*a*** and **11*a*** are arranged, relative to mirror **16** and source **12**, identically to means **10** and **11** of the previous embodiment.

Embodiment of FIGURES 6 and 7

In the embodiment of FIGURES 6 and 7, the transmitter means **10*b*** and photodetector **11*b*** are so constructed and arranged that the response of the photomultiplier to the light beam will be highly linear at all normal sound volumes, as well as being sensitive to even the smallest amplitude variations and to high frequencies. Except as will be noted specifically, elements **10*b*** and **11*b*** are identical to elements **10** and **11** of the embodiment of FIGURES 1–3, and have been numbered correspondingly.

Element **10*b*** is constructed with a mask **46** having a square opening **47** therein, two sides of the square being vertical and two sides being horizontal. Element **11*b*** is constructed with a mask **48** having a corresponding square opening **49** with vertical and horizontal sides, but opening **49** is laterally offset (horizontally) from the axis of the device. It follows that when the square light beam transmitted from transmitter **10*b*** is received by the photodetector **11*b***, it will not be registered with the square

opening **49** but instead will be horizontally offset therefrom as indicated by the numeral **51** in FIGURE 7.

The indicated horizontal offsetting assumes that the apparatus is oriented as shown in FIGURE 1, with the sound source **12** being directed horizontally and at substantially the same elevation as the light beam. The deflection caused by refraction of the light beam is thus horizontal in such manner that there is either a greater or lesser degree of registry of the light beam **51** with square opening **49**. The result is a curtain or shutter action which is highly linear, and in which at least part of the light beam is always registered with the opening **49**. The linearity results from the fact that a given deflection always produces a corresponding percentge change in the area of the beam received by the photomultiplier.

The sizes of the openings **47** and **49**, and the relative locations thereof, are made such that the light beam is never completely out of registry with the opening **49**, regardless of the amplitude of the sound wave transmitted from source **12**. There is thus a modulation action at all times, and never a stop-start action.

Various embodiments of the present invention, in addition to what has been illustrated and described in detail, may be employed without departing from the scope of the accompanying claims.

We claim:

1. A method of transducing audio sound waves into electrical waves, comprising the steps of generating a beam of light having a small dimension transverse to the direction of propagation of the beam, said dimension being smaller than the distance between a compression and an adjacent rarefaction of an audio sound wave, passing said beam of light through the open air adjacent a source of audio sound waves traveling through said air, and in such relationship to said sound waves that said small dimension is generally in line with the direction of propagation of said sound waves, directing said beam of light to a photodetector means whereby said means is caused to generate photo-electric current corresponding generally to said sound waves, and amplifying the current thus generated.

2. The invention as claimed in claim **1**, in which said method includes the step of selectively masking at least portions of said beam of light prior to impingement thereof onto said photodetector means whereby variation in the degree of refraction of said beam caused by said sound waves effects a variation in the degree of masking thereof to thus vary the response of said photodetector means.

3. A method of transducing sound waves into electric current, which comprises the steps of generating a beam having a width which is a multiplicity of times the thickness thereof, directing said beam through the air adjacent a source of sound waves traveling through said air and in such relation to said source that said beam is substantially tangential to a sphere having its center at said source, and disposing photodetector means in the path of said beam and so constructed that deflection of said beam caused by refraction thereof due to said sound waves varies the response of said photodetector means.

4. A method of transducing sound waves into electrical waves, comprising the steps of generating a light beam, transmitting said light beam through the air in advance of a source of sound vibrations traveling through said air, dispensing a mask in the path of said beam and having and edge portion which is so constructed and located that it is struck by said beam at all times during passage of normal sound waves through said beam, and disposing photo-detector means in the path of the portion of the beam transmitted past said edge portion of said mask.

5. The invention as claimed in claim **4**, in which said method includes the step of correlating the cross-sectional shape of said beam and the shape of said edge portion in such manner that the cross-sectional shape of the portion of said beam transmitted past said edge portion varies linearly in accordance with said sound vibrations.

6. A method of transducing sound waves into electrical waves, which comprises generating a beam of light, transmitting said beam of light through the ambient atmosphere at a region adjacent a sound-wave source which is disposed in said ambient atmosphere and which generates in said atmosphere sound waves adapted to effect refraction of said light beam passing therethrough in said atmosphere, disposing in the path of said refracted light beam a photodetector means so constructed that deflection of said beam caused by said refraction thereof varies the response of said photodetector means, and amplifying the output of said photodetector means to provide electrical waves corresponding to said sound waves.

7. The invention as claimed in claim **6**, in which said method further comprises the step of shaping said beam of light in such manner that, at least at the region which impinges against said photodetector means, said beam is a wide, thin band the thin dimension of which is generally parallel to the direction of propagation of said sound waves.

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DAVID G. REDINBAUGH, *Primary Examiner.*

JOHN W. CALDWELL, *Assistant Examiner.*